SIMULATION AND ANALYSIS DRAG AND LIFT COEFFICIENT BETWEEN SEDAN AND HATCHBACK CAR

MOHD KHALIL AZINGAH BIN SALLEH

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

Signature :
Name of Supervisor : Dr Yusnita Rahayu
Date : 20 November 2009

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :
Name : Mohd Khalil Azingah bin Salleh
ID Number : MH 07006
Date : 25 November 2009

Dedicated to my beloved parents

Mr. Salleh Bin Ahmad

Mrs. Fatimah Binti Ahmad

And

All my sisters and brothers

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I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. Special thanks should be given to my committee members. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this project.

ABSTRACT

This thesis presents research about the difference coefficients barriers and lift coefficients for two basic design types of sedan and hatchback cars. The objective of this thesis is to identify drag and lift coefficient.. Process simulation and analysis for both the model design was conducted with computer-aided drawing software and analyzed using software COSMOSFloworks. From the results of coefficients can be concluded that barriers and lift coefficients for both types of design is different. Restriction coefficient and lift coefficient for the hatchback design is much lower than the sedan design. This means that the hatchback design is more efficient and aerodynamics value is higher. This assessment and differences between the two designs is very meaningful for determining the design of more efficient designs in the car now. Results also able to enhance the security features on the car at once can reduce fuel consumption used. Results are also able to improve the design of the car in early development in the future.

ABSTRAK

Tesis ini membentangkan penyelidikan berkenaan perbezaan pekali hambatan dan pekali angkat bagi dua jenis rekabentuk asas kereta iaitu sedan dan hatchback. Objektif tesis ini ialah mengenalpasti pekali hambatan dan pekali angkat.. Proses simulasi dan analisis bagi kedua-dua model rekabentuk ini dijalankan dengan perisian lukisan bantuan komputer dan dianalisis menggunakan perisian COSMOSFloworks. Dari hasil keputusan dapat disimpulkan bahawa pekali hambatan dan pekali angkat bagi kedua-dua jenis rekabentuk ini adalah berbeza. Pekali hambatan dan pekali angkat bagi rekabentuk hatchback adalah lebih rendah berbanding rekabentuk sedan. Ini bermakna rekabentuk hatchback adalah lebih efisyen dan nilai aerodinamiknya lebih tinngi.Keputusan penilaian dan perbezaan antara kedua-dua rekabentuk ini amat bermakna bagi menentukan rekaan yang lebih efisyen dalam rekabentuk kereta sekarang. Keputusan juga berupaya meningkatkan lagi ciri-ciri keselamatan pada kereta sekaligus dapat mengurangkan penggunaan bahan api yang digunakan. Keputusan ini juga berupaya memperbaiki rekabentuk kereta tersebut di awal pembangunan pada masa hadapan.

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LIST OF SYMBOLS

C_D	Drag Coefficient
C_L	Lift Coefficient
F_L	Lift Force
F_D	Drag Force
Cp	Pressure Coefficient
Df	Friction Drag
b	Width
l	Length

LIST OF ABBREVIATIONS

CAD	Computer-aided drafting
CAE	Computer-aided engineering
FE	Finite element
RANS	Reynolds-averaged Navier –Stokes equation
DNS	Direct numerical simulation

CHAPTER 1

INTRODUCTION

1.1 Project Background

The importance of aerodynamics to several type car bodies model needs a development of drag and lift estimation to know how much the car performance on the road against air resistance beside to improve the stability, reducing noise and fuel consumption.

1.2 Problem Statement

Drag and lift will cause many problems on the performance of car model like instability, noise and fuel consumption. Thus, in this project the CAD models of sedan and hatchback bodies was simulated and analyze of their aerodynamics especially on the drag and lift estimation. In addition, using CFD and FEM analysis as a possible procedure were develop the drag estimation and aerodynamics studies on the body due to no wind tunnel in UMP.

1.3 Objectives

1. To determine average Drag Coefficient, C_D of sedan and hatchback car
2. To determine average Lift Coefficient, C_L of sedan and hatchback car

1.4 Project Scopes

1. Study of aerodynamics on road vehicle
2. Analyze the project with CFD for various car speeds
3. Determine where the regions of separated and reversed flow of our car design by using Cosmos Flow simulation software.
4. Determine how the trajectory of the flow through our car design is.

1.5 Summary

For the end of simulation and analysis, the objectives for this experiment will achieved by follow the scopes of project.

CHAPTER 2

FUNDAMENTAL OF AERODYNAMICS

2.1 Theory of Aerodynamics

In this section, the fundamental of aerodynamics is discussed to gain understanding in doing analysis of the project. The basics equation and terms in aerodynamics field or fundamental of fluid mechanics such as Bernoulli's Equation, pressure, lift and drag coefficient, boundary layer, separation flow, and shape dependence are studied.

2.1.1 Bernoulli's Equation

Aerodynamics play main role to defined road vehicle's characteristic like handling, noise, performance and fuel economy. The improvement on the characteristic related through the drag force which is ruled by Bernoulli Equation. Basic assumptions of Bernoulli's Equation for an air flows are;

- Viscous effects are assumed negligible
- The flow is assumed to be steady
- The flow is assumed to be incompressible
- The equation is applicable along streamline

$$p + \frac{1}{2}\rho v^2 = constant \qquad (2.1)$$

From equation (2.1) shows the increasing of velocity will case the decrease in static pressure and vice versa. On the movement of road vehicle will produce a distribution velocity that's create the skin friction due to viscous boundary layer which act as tangential forces (shear stress) then contribute drag. Beside that, force due to pressure also created which acts perpendicular to the surface then contribute both lift and drag forces. The Bernoulli's Equation from equation (2.1) gives the important result which is ;

Static pressure + Dynamic Pressure = Stagnation Pressure.

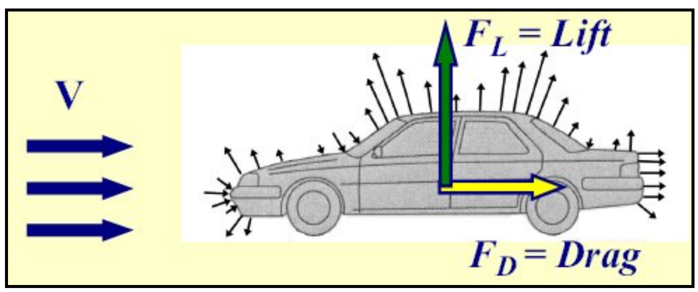

Figure 2.1 Drag and lift force due to pressure from velocity distribution [Adam Heberly, 1999]

2.1.2 Pressure, Lift and Drag Coefficient

Drag can generate by two main perspectives: [Clancy, L.J. (1975)]

- From the vehicles (body)
- From the moving fluid

From the two perspectives, three major coefficients were produced from the two basic of aerodynamics forces. The first force is pressure distributions that normal (perpendicular) force to the body which is will produce pressure, drag and lift coefficient. The second force is shear force that tangential (parallel) to the surface of body's vehicle where is contribute drag coefficient only.

2.1.2.1 Pressure Coefficient

The equation for coefficient of pressure (*Cp*) due to dynamic pressure can derive as: [John D.Anderson. (2007)]

$$Cp = \frac{p - p_\infty}{\frac{1}{2}\rho v_\infty{}^2} \tag{2.2}$$

The equation of dynamic pressure defined as; [John D.Anderson. (2007)]

$$p_{tot} - p_\infty = \frac{\rho}{2} v_\infty{}^2 \tag{2.3}$$

In term of local velocity, the pressure coefficient (only valid for incompressible flow) can derive as ; [John D.Anderson. (2007)]

$$Cp = 1 - \frac{v^2}{v_\infty{}^2} \tag{2.4}$$

The form of equation (2.4) is from the relation equation (2.2) and equation (2.5) as shown below ; [John D.Anderson. (2007)]

$$p - p_\infty = \frac{1}{2}\rho(v_\infty{}^2 - v^2) \tag{2.5}$$

From the equation (2.4) where the local velocity on velocity is zero, the pressure coefficient is equal to 1.0 and when $v=v_\infty$, the pressure coefficient will be zero. While from equation (2.2) where $p=p_\infty$, Cp was become zero also. Pressure coefficient would become negative, since the local velocity is larger than the free stream velocity, v_∞. Therefore, some typical value of pressure coefficient can summarize on table as shown in Table 2.1 below.

Table 2.1: Typical Values of Pressure Coefficient, *Cp*.
[Clancy, L.J. (1975)]

Location	**Cp**	**Velocity, v**
Stagnation Point	1.0	0
On body's vehicle	0-1.0	$v< v_\infty$
On body's vehicle	Negative	$v > v_\infty$

2.1.2.2 Drag Coefficient

As was informed before the net drag is produced by both pressure and shear forces, thus the drag coefficient (C_D) for a vehicle body can define as: [John D.Anderson. (2007)]

$$C_D = \frac{D}{\frac{1}{2}\rho v_\infty{}^2 A} \tag{2.6}$$

Where D is the drag and A is the frontal area

Since, the C_D was defined as shown in equation (2.6). Thus, the drag force can derive as; [John D.Anderson. (2007)]

$$D = \frac{1}{2}\rho v_\infty{}^2 C_D . A$$

(2.7)

Besides that, the drag coefficient, C_{df} can derive from friction drag, D_f, on a flat plate as: [John D.Anderson. (2007)]

$$C_{df} = \frac{D_f}{\frac{1}{2}\rho v^2 b.l} \tag{2.8}$$

Where D_f is friction drag, b and l are width and length of flat plate.

2.1.2.3 Lift Coefficient

The lift force can be determined if the distribution of dynamic pressure and shear force on the entire body are known. Therefore the lift coefficient (C_L) can indicate as: [John D.Anderson. (2007)]

$$C_L = \frac{L}{\frac{1}{2}\rho v_\infty{}^2 A} \tag{2.9}$$

Where L is lift force and A is the frontal area

Pressure and shear stress distribution is difficult to obtain along a surface for non geometry body either experimentally or theoretically but these to value can be obtained by Computational Fluid Dynamics (CFD).

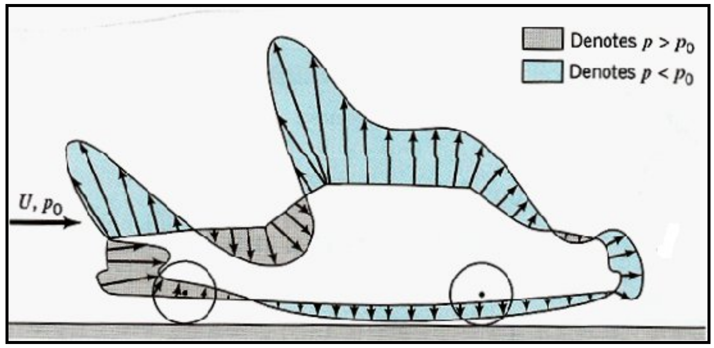

Figure 2.2: Pressure distributions on the surface of an automobile
[J. Katz (2006)]

2.1.3 Boundary Layer

Boundary layer study in aerodynamics can be describe on a flat plate where is develop with two types flow which is laminar and turbulent flow. Due to fluid viscosity, a thin layer will exist when the velocity parallel to the static flat plate and then gradually increase the outer velocity. The thickness of boundary layer also increases with the distance along the flat plate's surface .

Normally, the boundary layer is start from laminar flow and develops into turbulent flow. These two types of flow can determined with change of Reynolds number. Between the laminar and turbulent, form of transition region start occur when the change on laminar flow into turbulent flow. The variation of boundary layer thickness is shown in Figure 2.3: